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WHITE PAPER

Ferrous Measurements Used in Machine Oil Analysis Condition Monitoring



Introduction

Ferrous alloys make up the bulk of most lubricating machine surfaces. The physical strength and wear properties of cast iron and steel alloys make these good choices for a machine wear surface. The hydrodynamically lubricated surfaces are designed to wear and exfoliate wear particles into the lubricant at a slow and modest rate. These fine particles are generated by abrasion between the surfaces and lubricant forming a constant regenerating layer at the wear surface extremity. These particles are fine ferrous wear particles and they can be used to indicate when the oil is dirty and needs to be changed or when the forces at the wear surface cause breakdown of the normal lubricating layers and larger more severe ferrous wear particles are produced. The latter scenario sees a breakdown in the normal abrasive wear mechanism at the lubricating surface and a switch over to a more severe adhesive abnormal wear mode. Once the wear surface has been compromised and large adhesive forces take over, which remove larger particles, this can quickly lead to catastrophic failure of the machine if not addressed.

Various ferrous monitoring techniques are available to the oil analyst in order to make recommendations based on the physical state of the machine components.

Total ferrous monitors vs particle monitors

Ferrous devices can be broadly broken down into total ferrous monitors and ferrous particle monitors. The total ferrous monitors will tell the analyst the total ferrous content in the oil and also give an idea of any transitions into a more severe wear regime. Spotting the transition from normal wear to severe or abnormal wear depends on the accuracy of the device. Periodic sampling of a closed loop lubricating system will always see a steady increase in fine total ferrous material until the oil is changed. These devices act as good screening tools for additional testing in both labs and end user environments because the measurement is quick and easy to perform.

The ferrous particle monitors are particularly useful in identifying critical wear transition points and break down of film thicknesses. These are the most important devices in identifying large particles and stopping any further damage to the machine and wear surfaces.

Total ferrous vs ferrous particles – what's the difference?

The particulate that makes up a typical total ferrous reading is everything ferrous in the oil that has worn off the machine. These particles are very fine in nature based on the inherent friction-reducing tribology created at the wear surface. As these particles continue to make their way through the lube system they become smaller and more ground up between the machines wear surfaces. Based on their size there are very few loss mechanisms during a cycle and the total ppm concentration will rise steadily.

Large particles are produced due to abnormal forces at the wear surface and are not part of the normal running operation of the machine. This could be caused by anything, such as: incorrect lubricant, contamination, oil degradation, or simply higher loads and speeds than the machine's designed to handle. The large particles themselves appear in much smaller numbers in an overall particle distribution and contribute very little in ppm value to a total ferrous measurement. This means that the best way to quantify and trend them accurately is by a particle count.

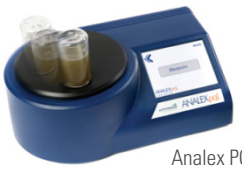
Both total ferrous and ferrous particle monitors are equally important but it's essential to understand that they monitor different aspects of the wear spectrum. The transition from normal to abnormal wear is often hard to detect with just one device.

FerroCheck 2000





Midas



Analex PQ

Total ferrous monitor instruments

■ TOTAL FERROUS MONITORS

PROS
- Easy to use
- Fast results
- Relatively inexpensive
- Grease measurement is possible

CONS
- No information about individual particles

Total ferrous monitors use the change of inductance to quantify the total ferrous content when an unknown sample containing ferrous material is passed through a coil of wire. This is typically done by dropping a vial containing a few milliliters of oil into the coil. These devices typically report either in ppm or a non-dimensional index to allow assets to be trended for ferrous content. Careful consideration of the drive electronics and signal processing, together with temperature compensation, can result in detection limits at single digit ppm. These techniques, specifically the drive and gain amplifier electronics, can be used to expand the output beyond the 1000 ppm range into the % range. This is typically useful for grease application samples, which are suited to this type of measurement.

■ FERROUS PARTICLE MONITORS

Ferrography



Direct Reading (DR) ferrography device

PROS
- Total ferrous measurement
- Particle size
- Particle distribution

CONS
- Need skilled operator
- Time consuming

Particle ferrous monitors are used primarily to detect the large ferrous particles in the overall sample distribution as opposed to the total ferrous quantity. There are various techniques available to do this. Until recently Ferrography coupled with Direct Reading (DR) Ferrography was used to identify changes in large ferrous particles vs non-ferrous wear. The two devices have traditionally worked in tandem together. The DR device is used as a screening tool for Ferrography and works by collecting ferrous particles using a magnetic field as they flow under gravity through a tube. The larger particles with larger mass are pulled out first by the magnetic field resulting in the partial blockage of a photo diode which can then be used to quantify the large ferrous wear.

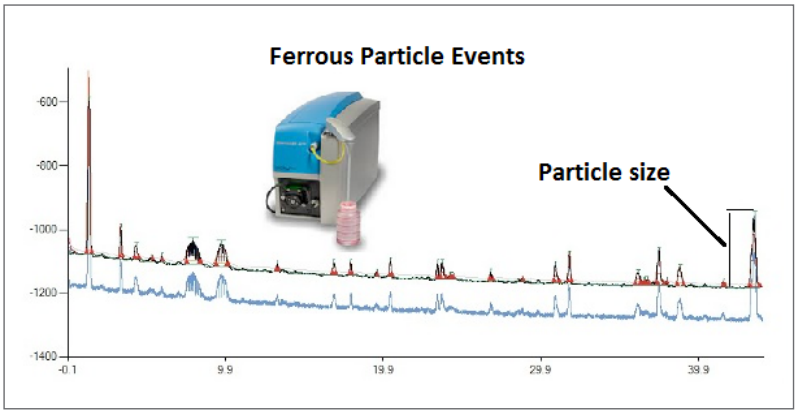


Ferrography laboratory

Ferrography is a technique that utilizes a trained operator to identify ferrous vs non-ferrous particles and other morphological attributes to arrive at a root cause conclusion of the failure mode within the machine. The ferrogram is a substrate that is made by applying a very strong magnetic field to the oil flowing across it. The orientation and deposition pattern allows the operator to distinguish between the large (severe wear particles) and the benign wear and draw conclusions based on morphological attributes about the particles using microscopy. Ferrography is a very powerful tool, but is time consuming, expensive and requires a trained operator to perform the analysis.

Ferrous particle flow detectors

A recent innovation in ferrous particle monitoring is the flow magnetometer, which uses a similar inductance principle as total ferrous magnetometers but detects the signals from individual particles as they flow through the coil. The amplifier electronics, coil winding and wire gages are adjusted to be able to detect particles in the flow down as small as 20 mm. In this type of device the flow of oil also needs to be calculated in order to normalize the counts per unit volume so they can be consistently trended and compared against total particle counts that report the same units.



An example showing particle events from the LaserNet 230 ferrous particle flow detector

PROS
- Total ferrous
- Particle size
- Particle distribution
- Automated operation

CONS
- Relatively expensive

This type of device is suited to a flow system and it has been added to the LaserNet Fines flow path together with a total ferrous ppm magnetometer to differentiate between ferrous and non-ferrous large particles and monitor total ferrous ppm at the same time. Differentiating the direct imaging total particle count from the ferrous count for given large particle sizes and accurately determining the oil flow rate using the particle velocity makes this device a comprehensive, all-around tool for detecting ferrous wear in different regimes of lubrication.

Other devices with less sensitivity like the GasTOPS MetalScan provide excellent particle detection for very large ferrous particles >170mm. The signals provided at this level also provide information to separate out ferrous from non-ferrous debris by looking at the phase difference in the signal.

Summary

Ferrous wear is one of the most important parameters to monitor as part of a condition based maintenance program. The main goal of such a program is to identify the transition from normal wear to abnormal wear and take action before the machinery fails. The technique chosen depends upon cost, equipment and personnel available to monitor ferrous wear.

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